1. (30 points) The carrier concentrations for an NPN bipolar transistor operating in the forward active region are shown at right. Calculate the collector current, $I_C$, that this device will conduct under these conditions. 

Use: $T = 27^\circ C$, $A = 100 \, \mu m^2$, $D_N = 30 \, cm^2/sec$, $W_B = 0.5 \mu m$ 

$n_{p0} = 2.1 \times 10^4 \, carriers/cm^3$, $V_{BE} = 0.7V$, $V_{BC} = -1V$.

(Note that $n_{p0} = n_i^2/N_A \neq n_p(0)$ shown in the figure.)
2. (30 points) Use the small-signal model and nodal analysis to show that the output impedance for the MOS Wilson current mirror shown at right is given by: \( R_{\text{out}} \approx r_{ds_2} (1 + g_{m_2} r_{ds_3}) \), neglecting body effect.

Do NOT use feedback analysis or the “short cut approach”
3. For the differential amplifier shown at right:
   a) (20 points) Draw the differential and common-mode half-circuits
   b) (20 points) Find the DC differential-mode gain

Use: $\beta_F = 100$, $V_A = 100V$, $I_{bias} = 100\mu A$, $k'_N = 100\mu A/V^2$,
$k'_P = 40\mu A/V^2$, $\lambda_N = 0.1$, $\lambda_P = 0.2$, $\gamma = 0$ (neglect body effect),
$W/L_3 = W/L_4 = W/L_8 = 20/0.4$, $W/L_9 = 40/0.4$,
$W/L_5 = W/L_6 = W/L_7 = 50/0.4$, $T = 27^\circ C$

Assume $V_b$ is chosen to keep all MOSFETs saturated and
all bipolars in the forward-active region. Also assume that a
common-mode feedback circuit (not shown) sets $I_{d9} = I_{d5} + I_{d6}$. 
extra work space for problem 3
BONUS (5 points) : For the differential amplifier shown in problem 3 above, which transistor has the biggest impact on CMRR? Explain your answer.